INTRODUCTION

This support document supplements Chapter 61 Water Quality Standards (567) (effective June 16, 2004). The two major subjects discussed are the Wasteload Allocations (WLAs) and the modeling theory. Iowa Department of Natural Resources does WLAs for facilities that discharge treated wastewater into waterways in order to assure that the permitted effluent limits meet applicable state Water Quality Standards. The calculation of a WLA is divided into three steps. Step one uses hand calculations, step two uses the DNR's Modified Iowa Model, and step three uses the Vermont QUAL-II Model.

There are two mathematical modeling theories or computer programs that are used by the Department. DNR's Modified Iowa Model can be used as a quick screening tool to eliminate the advanced wastewater treatment requirements for permitted discharges on potentially water quality limited stream segments. Staff will develop final WLAs for dischargers on WQ-based stream reaches using the Vermont QUAL-II Model. The Vermont version of QUAL-II meets all the requirements of an appropriate model for the State of Iowa since it includes excellent algal kinetics, preferential uptake of ammonia, and the simulation of all inorganic and organic forms of nitrogen and phosphorus.

This document is posted on the Iowa Department of Natural Resources Environmental Services Division website in the Water Quality Bureau section.

WASTELOAD ALLOCATIONS

Wasteload allocations are determined for wastewater treatment facilities or other permitted discharges that discharge into waterways in order to assure that applicable state Water Quality Standards are met within the watershed basin. Wasteload allocation analyses are performed for monthly conditions using the projected 20 year Average Dry Weather (ADW) and Average Wet Weather (AWW) wastewater discharge flows entering a receiving stream which is at the design low stream flow or protected flow regime. The acute, chronic, and human health wasteload allocation calculations will use the applicable design low flow noted in the following Table.

Table IV-1 Design Low Stream Flow Regime

Type of Numerical Criteria	Design Low Flow Regime
Aquatic Life Protection (TOXICS)	
Acute	$1Q_{10}$
Chronic	$7Q_{10}$
Aquatic Life Protection (AMMONIA – N)	
Acute	$1Q_{10}$
Chronic	$30Q_{10}$
Human Health Protection & MCL	
Non-carcinogenic	$30Q_5$
Carcinogenic	Harmonic mean
Bacteria	
E. coli	$7Q_{10}$
CBOD	$7Q_{10}$

$1Q_{10}$ means 1-day, 10-year low flow,
$7Q_{10}$ means 7-day, 10-year low flow,
$30Q_5$ means 30-day, 5-year low flow,
$30Q_{10}$ means 30-day, 10-year low flow,
Harmonic Mean is calculated by dividing the number of daily flows in the database by the sum of the reciprocals of those daily flows.
CBOD = Carbonaceous Biochemical Oxygen Demand.

Care must be taken in selecting the design discharge flow, which would be expected to be entering the receiving stream during the design low stream flow or protected flow conditions. Most WLA calculations will use the ADW or AWW design flows. Design flows are obtained from facility plans, engineering reports, or constructed permits. IDNR staff should approve the design flows used for wasteload allocation calculations.

Wasteload allocation analysis will be performed on the receiving streams designated as Class A, B, and/or C with existing or proposed wastewater discharges and on the tributaries classified as general use that receive wastewater discharges. This analysis will incorporate accurate consideration of field conditions for each type of stream. The specific assumptions and considerations that are part of the analysis are discussed below.

Assumptions

In order to determine wasteload allocations for discharges within the state, specific assumptions are required. Identification of the major items required to evaluate and determine wasteload allocations are identified in the following list.

1. Determination of design low stream flows is required for each stream segment modeled. The calculation of low flows on ungaged stream reaches are based on data from Plate 3 and 4 of the USGS publication, "Annual and Seasonal Low-Flow Characteristics of Iowa Streams," March 1979. Low flow at gaged stream locations is obtained from the USGS Open-File Report "Statistical Summaries of Selected Iowa Streamflow Data".

   For some waterways, a Protected Flow (P.F.) has been established that replaces the statistical based low flows found in the USGS publications. Protected flows can be found in the document titled Protected Flows for Selected Stream Segments, February 1, 1996. The Protected Flows will be used in lieu of the natural flows noted in Table IV-1 unless the statistical natural flow is larger (higher). For example, a small designated stream may have a $7Q_{10}$ = 0.2 cfs, $1Q_{10}$ = 0.15 cfs, $30Q_{10}$ = 0.3 cfs, $30Q_5$ = 0.6 cfs and a P.F. = 0.5 cfs. The 0.5 cfs protected flow would be substituted for the $1Q_{10}$, the $7Q_{10}$, and the 30 Q_{10}, and the $30Q_5$ would be equal to 0.6 cfs.

2. The major objective of the hand calculations and the modeling activities is to assure that Iowa Water Quality Standards are met with the permitted and future effluent discharge flows. Modeling activities determine an allowable wasteload allocation by varying the allocation for a discharger (or dischargers) until the water quality model demonstrates that the instream oxygen concentrations would be maintained above the dissolved oxygen criterion values. In addition, the modeling will determine instream ammonia nitrogen concentrations below the water quality criteria levels in the designated stream segments at the critical stream flow conditions as shown in Table IV-1, or at the protected low flow. Hand calculations directly set the wasteload allocation through a dilutional or mass balance relationship.

3. One hundred percent of the stream's low flow is used to assimilate the nonconservative pollutant Carbonaceous Biochemical Oxygen Demand (CBOD) in the wastewater discharge. The stream

flow contained in the defined mixing zone is used to assimilate the conservative and toxic pollutants such as ammonia nitrogen (NH_3-N), TRC, metals, cyanide, and toxics. Specific water quality-based $CBOD_5$ and NH_3-N permit limits will be noted as long as the calculated values are more stringent than those assumed for normal domestic standard secondary treatment facilities (see paragraph 7 below). For those stream reaches with a protected flow, the greater (larger) flow value (natural or protected flow) will be used. Continuously discharging sources of wastewater are included in the modeling procedure (i.e. continous discharge lagoon, activated sludge, non-contact cooling water). Most waste stabilization ponds treating typical domestic wastewater and having 180 day controlled discharge capabilities are normally assumed not to be discharging at low stream flow conditions.

The wasteload allocation resulting from the hand calculation or modeling calculations will be the basis for establishing both the maximum and the average loading and concentration which a facility could discharge.

4. Ultimate carbonaceous CBOD is assumed to be 1.5 times the $CBOD_5$. This ratio may be changed if site specific data indicates a different value would exist for a particular treatment process or waste characteristic.

5. Average stream temperature and pH are assumed to be approximated by the following table unless impacted by a thermal type discharge. Table IV-2 represents monthly average values from ambient monitoring data contained in the EPA STORET data system.

Table IV-2
Statewide pH and Temperature Values

Month	**pH**	**Temp°C**
January	7.8	0.6
February	7.7	1.2
March	7.9	4.3
April	8.1	11.7
May	8.1	16.6
June	8.1	21.4
July	8.1	24.8
August	8.2	23.8
September	8.0	22.2
October	8.0	12.3
November	8.1	6.0
December	8.0	1.6

6. In order that the reaeration rate constant be applicable to winter time ice conditions, the amount of ice cover on the stream is estimated. It is assumed that the effective amount of aeration should be inversely proportional to the percentage of ice cover. The winter reaeration rate constant for each stream reach is then determined by multiplying the temperature corrected rate constant by the adjusted fraction of open water in the reach. Experimental data was used to find the adjusted fraction of the open water in the reach. Ice cover estimates are based upon general climatological conditions for the basin and upon field observations. Open water fraction (ICE) is equivalent to

$$1-\left(0.95\times\frac{\text{percent ice cover}}{100}\right).$$

<u>Example:</u>

Winter: 100% ice cover results in open water fraction of 0.05

Summer: 0% ice cover results in open water fraction of 1.0

7. Since limited data is available to describe each individual wastewater treatment facility's effluent dissolved oxygen concentrations, the following values were assumed for each class of wastewater dischargers:

Wastewater Treatment Type	Summer DO (mg/l)	Winter DO (mg/l)
Secondary Treatment	3.0	4.0

Advance Treatment	5.0	6.0
Aerated Effluents	6-8	6-8
Industrial Plant	Each Discharge Handled Individually or Varies	

8. From analysis of available effluent data it has been assumed that a well operated and maintained secondary treatment plant treating normal domestic wastewater should be able to achieve 10-15 mg/l of NH_3-N in July and August and 15-20 mg/l of NH_3-N from September through June. Special consideration will be given when monitoring data from a wastewater treatment facility is greater than these levels.

9. Best practicable or available technology effluent limitations described by EPA guidelines are used for industrial dischargers when they are available and sufficient. Otherwise, the actual allowable wasteload required to meet stream standards is determined and identified as the wasteload allocation for that discharger. For municipal and industrial discharges with toxic parameters on streams classified as only general use, the allowable wasteload will be based on data contained in the U.S. EPA 304(a) criteria documents. These criteria documents will be used to determine in stream toxic criteria for general use streams.

10. The background water quality of the streams being modeled was assumed to have saturated dissolved oxygen concentrations, an ultimate CBOD concentration of 6.0 mg/l, and an NH_3-N concentration of 0.0 mg/l (July and August) and 0.5 mg/l (September through June).

11. The water quality of the groundwater contribution was assumed to have a $CBOD_5$ of 4 mg/l and an NH_3-N concentration of 0.0 mg/l (July and August) and 0.5 mg/l (September through June).

12. Mixing of wastewater and tributary flows with the main body of water is site specific and it is based on the allowed percentages noted in Chapter 61, WQS. Mixing is not assumed to be complete and instantaneous.

13. Uniform lateral and longitudinal dispersion (plug flow) is assumed for the stream constituents as they move downstream.

Wasteload Allocation Procedures

The wasteload allocation procedure section is divided into two subsections, conventional pollutants and toxics. This division is necessary because the Water Quality Standards (Chapter 61) require different instream criteria to be met at different locations in the receiving stream.

A. Conventional Pollutants: The calculation of a wasteload allocation for conventional pollutants will consider the instream dissolved oxygen impacts of carbonaceous biochemical oxygen demand (CBOD), ammonia nitrogen (NH_3-N), and any other oxygen demanding materials. The wasteload allocation for NH_3-N and other oxygen demanding materials is also addressed in the Toxics section, as these pollutants are also defined as toxics. It should be noted that this section of the wasteload allocation procedures does not consider other types of conventional pollutants, such as suspended solids, oil, and grease, because these pollutants are assumed to have little oxygen demand.

The wasteload allocation of the oxygen demanding pollutants are determined directly from the results of water quality models which account for the fates of the pollutants as they move down the receiving stream.

The two water quality models used to determine wasteload allocations are QUAL-II and Modified Iowa. They require additional data on algal kinetics and are limited to short stream reaches. Due to a lack of algal kinetic rate constants on many stream reaches, the extensive number of designated stream reaches in Iowa, and other factors, a sequencing/screening approach is being used to arrive at the final WLA. The sequencing of calculating a WLA is divided into three different steps. Step one uses hand calculations, step two uses the Modified Iowa model, and step three uses the QUAL-II model. Any WLA, new or recalculated, for any continuous discharging treatment facility is determined by following the sequence. Requests for a WLA will be handled as soon as possible. However, if a back log begins to occur, all requests will first be hand calculated (if necessary). This should address at least 50% of all requests. The remaining requests will be modeled with Modified Iowa and by the QUAL-II model if required.

1. Hand Calculations

The use of hand calculations is intended to provide a quick method to determine if a CBOD discharge of standard secondary or BPT/BAT[1] from the treatment facility is causing a water quality violation. This step could be skipped if the treatment facility is known to be causing a water quality violation, or if it is felt that the facility obviously requires advanced treatment. This calculation, as with the use of the water quality models, will be performed using the design low stream flow ($7Q_{10}$) or protected flow, the treatment facilities design dry and wet weather flow (if applicable), the appropriate standard secondary $CBOD_5$, and assumed ammonia levels. With the various alternative treatment limits allowed in the definition of standard secondary, the specific permitted $CBOD_5$ levels for the selected (or expected) type of treatment must be used in the hand calculations. This hand calculation approach uses a conservative assimilation rate of $CBOD_5$ (20 lbs/d/cfs) which has been derived from past modeling results.

a. Available Stream Capacity

Staff will calculate the available stream capacity for $CBOD_5$ below the discharger in question by the following relationships. $CBOD_L$ is the stream capacity (or loading) carbonaceous BOD_5 in pounds per day.

For $CBOD_5$

$$(Q_u + Q_d)\ 20\ \text{lbs/d/cfs} = CBOD_L \qquad (1)$$

where:

Q_u = Critical stream flow, cfs

Q_d = Dry weather design discharge flow, cfs

$CBOD_L$ = Stream capacity carbonaceous BOD_5, lbs/day

b.   Treatment Facility Loading

[1] BPT = Best Practical Treatment are EPA derived minimum treatment levels that are required for both municipal and industrial wastewater treatment facilities. BAT = Best Available Treatment are EPA derived levels for industry.

The loading from the treatment facility at its specific standard secondary level is given by the following equation.

For BOD_5

$$(CBOD_5)\ (8.34)(Q_d) = CBOD_e \qquad (2)$$

where:

$CBOD_5$ = Technology or standard secondary $CBOD_5$, mg/1
Q_d = Dry weather discharge flow, mgd
$CBOD_e$ = Carbonaceous BOD_5 in the effluent, lbs/day
8.34 = Conversion factor

c. Stream Capacity vs. Effluent Loading

If the stream $CBOD_5$ capacity ($CBOD_L$) above is larger than the technology or standard secondary $CBOD_5$ ($CBOD_e$), the stream is termed effluent limited for CBOD and no additional modeling is required. The effluent limitation for $CBOD_5$ will be the level set for standard secondary or the technology level.

If according to the above comparison the stream is not effluent limited, the stream should be modeled using the Modified Iowa model. However, unusual factors or stream conditions might warrant undertaking the next calculation step even if the stream is effluent limited. These unusual conditions might include: several dischargers within close proximity, discharge of large algal concentrations, discharge of elevated ammonia nitrogen levels, and loadings to the stream at or near stream capacity.

2. Use of Modified Iowa Model

When it is found that a treatment facility cannot discharge at a standard level, the staff will set up and run the Modified Iowa model described in greater detail below. For most dischargers, the previous model runs of 1976-1982 can be used as the basis input data. Minor modifications in data formatting are required to incorporate the new algal relationships. The Modified Iowa program will only be used on the stream reach below the discharge, not the entire river basin.

For each discharger, a monthly or seasonal (spring/fall, summer and winter) run normally will be made using the same dry and wet weather design flow as used in the hand calculations above. These monthly or multi-seasonal runs are necessary because of the monthly or potential seasonal ammonia nitrogen wasteload allocations developed in the Toxics sections. If the seasonal run was performed, the month that has the most stringent conditions should be used to represent the specific season. It is necessary to calculate the toxics based WLA for ammonia nitrogen for use in the modeling of conventional pollutants. In many instances, the protection of the ammonia acute and chronic criteria will be more restrictive than the oxygen demand exerted by the ammonia.

Calibrated rate constants and literature values found in Table IV-3 (page 72) will be used for the modified model. Detailed calibrations will be carried out only for the QUAL-II model. The purpose of the modified model is to be a quick modeling exercise with minimum staff time. Reiterative model runs will be made varying effluent $CBOD_5$ from standard secondary and varying NH_3-N to more stringent levels until model responses shows that dissolved oxygen water quality standards are met in the designated reach.

If the modeling demonstrates that standard secondary treatment will meet the water quality standards, then that level will be the effluent limit for the treatment facility. If the modeling shows that advanced treatment is required, the stream reach will be modeled using the QUAL-II program to determine the final wasteload allocations.

3. Use of the QUAL-II Model

When it is found that a treatment facility cannot discharge at a standard secondary level as evaluated by the above two calculations, then staff will set up and run the QUAL-II model described above. As with the Modified Iowa model, QUAL-II will be run only on the stream reach below the discharger. It is within this short reach that the steady state assumptions used in the model are valid.

Setting up the stream run under QUAL-II format requires additional staff effort. However, some of the physical stream data found in the Modified Iowa model's stream run will be used with the QUAL-II stream run. Whenever possible, calibrated rate constants will be used. These calibrated values can come from data obtained from intensive stream surveys on the receiving stream, from calibration data on similar streams, or from literature values shown in Table IV-4 (pages 84-85). The same dry and wet weather design flow and background ammonia nitrogen values will be used, as above.

For each discharger, April through June (Spring), September through October (Fall), July and August (Summer), and November through March (Winter) model runs normally will be made varying the effluent $CBOD_5$ **(**and NH_3-N if necessary) if the model response shows that dissolved oxygen water quality standards are met in the designated reach. The final wasteload allocation will be the combination of $CBOD_5$ and NH_3- N which just meet the standards.

Specific NH_3-N limitations will be noted in the wasteload up to the standard secondary range mentioned above (15 mg/l summer and 20 mg/l winter and spring/fall). This will indicate the available stream capacity for NH_3-N and allow for careful design of nitrification facilities. $CBOD_5$ limitations will be noted as carbonaceous or inhibited values except for certain industrial facilities for which BPT/BAT limits are expressed as BOD_5. An attempt will be made to establish a $CBOD_5$ to BOD_5 relationship for each industry for use only in modeling of the stream's assimilative capacity.

B. Toxic Parameters: The wasteload allocation (WLA) for toxic parameters will not require the use of the two above mentioned models. However, it is necessary to determine the characteristics of the regulatory Mixing Zone (MZ) and Zone of Initial Dilution (ZID). The regulatory MZ will be determined the default values noted in Chapter 61, WQS, from data supplied by the applicants, or from use of the MZ model noted in Appendix B, Mixing Zone Studies. Department staff will use the default values or practiced use stream characteristics obtained from file information unless the applicant provides additional data that demonstrates that the characteristics of the outfall or the discharge location do not match the assumptions used in the development of this model. Other models will be used where appropriate or as they become available.

The Appendix presents the basic field data requirements of a MZ study to be provided by an applicant for recalculation of the local MZ. The purpose of the recalculation is to more closely approximate the local MZ using site specific data instead of statewide data. Contact should be made with the Department's Water Resources Section prior to beginning any field study.
The calculations of toxic WLAs involves the incorporation of the ‘regulatory’ MZ and ZID for each wastewater treatment facility, the design effluent flow rates, and the applicable acute and chronic water quality criteria. The determination of the MZ and ZID are presented in a separate section (pages 51-

53). This Toxics section uses these defined zones and the corresponding flow in establishing the WLAs for toxics.

Calculations:

As noted in Subrule 61.2(4) of the Water Quality Standards, the chronic criteria must be met at the boundary of the MZ and the acute criteria must be met at the boundary of the ZID. A simple mass balance of pollutants will be used to meet these boundary conditions.

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) \qquad (3)$$

where:

C_b = Background concentration, µg/l
Q_b = Stream flow in the MZ or ZID, cfs
Q_o = Effluent flow, cfs
C_s = Applicable water quality standard, µg/l
C_o = WLA concentration, µg/l

This equation is solved four times for C_o: one time each for ADW acute, ADW chronic, AWW acute, and AWW chronic. The results are wasteload allocations for the protection of the acute criteria and wasteload allocations for the protection of the chronic criteria. These wasteload allocation values are then carried forward to the Permit Derivation Procedure section (pages 55-56).

C. Ammonia Nitrogen: Special consideration must be given to the calculations of wasteload allocation for ammonia nitrogen. First, water quality standards list the ammonia criteria as a function of pH and/or temperature because of the influence these parameters have on the toxic form of ammonia (unionized). Therefore, it is necessary to establish the applicable 'average' instream pH and temperature values of the designated stream segment receiving the effluent before the acute and chronic ammonia criteria can be selected. After the adoption of the 2000
new ammonia criteria, the ammonia criteria will be calculated monthly based on pH and/or temperature values. As a result, the ammonia WLAs will also be monthly instead of seasonal.

Second, the Mixing Zone (MZ) flow and the Zone of Initial Dilution (ZID) flow are a function of the dilution ratio of the receiving stream to the effluent. This dilution ratio is defined in Chapter 60 of the department rules for a specific discharger as the ratio of the critical stream flow to the effluent design flow. As shown in Table IV-1 for ammonia, the chronic and acute wasteload allocations are calculated based on different design low stream flows, i.e. $30Q_{10}$ stream flow for chronic WLA's and $1Q_{10}$ stream flow for acute WLA's. The dilution ratios for ammonia are calculated using $30Q_{10}$ or $1Q_{10}$ stream flow and the effluent discharge flow as discussed below.

1. <u>Dilution Ratios</u>

The flow used in the wasteload allocation calculations for the MZ and ZID vary with the type of dilution ratio. The discharger will be separated into one of three types based on the river and discharge flows:

a. Type 1: The ratio of stream flow to discharge flow is less than or equal to 2:1 -
MZ is 100% of the $30Q_{10}$ ZID is 5% of the $1Q_{10}$

b. Type 2: The ratio of stream flow to discharge flow is less than or equal to 5:1 and greater than 2:1 –
MZ is 50% of the $30Q_{10}$ ZID is 5% of the $1Q_{10}$

c. Type 3: The ratio of stream flow to discharge flow is greater than 5:1 –
MZ is 25% of the $30Q_{10}$ ZID is 2.5% of the $1Q_{10}$

2. <u>Mixing Zone: Boundary pH and Temperatures</u>

For all three types of MZ ratios noted above, the pH and temperature values used to calculate the water quality standards for the boundary of the mixing zone are defaulted to the statewide background values (for statewide values, see Table IV-2) unless local values or regional values are provided by the discharger.

a. *Local Values:* If the applicant desires that local values be used, they must supply a minimum of 2 years of pH and temperature readings and sample at least once a week. Preferably, the readings will be obtained during the low flow conditions will be typical of 24-hour conditions. Monitoring values may be obtained either from upstream of the outfall and the discharge or from the approximate location of the downstream limits of the ZID and the MZ.

b. *Regional Values:* If a facility, at a reasonable distance upstream of the applicant, has supplied background readings of pH and temperature that the department believes can be used as background, these readings will be used instead of the statewide averages. Normally readings at the end of an upstream facility MZ will not be used as background for the facility unless these readings are from close proximity to the applicant's outfall.

3. Zone of Initial Dilution: Boundary pH and Temperatures

The acute water quality criteria for ammonia will be based upon one of the following methods:

a. For Type 1 facilities, the acute water quality criteria for ammonia will be calculated based on the effluent pH and temperature values.
b. For Type 2 and 3 facilities, the acute water quality criteria for ammonia will be based on a pH calculated using the following equation.

$$\text{ZID pH} = -\text{LOG}\{0.5 * [10^{-(\text{background pH})}+10^{-(\text{discharge pH})}]\} \qquad (4)$$

$$\text{TEMPERATURE} = \frac{(F_B * T_B) + (F_D * T_D)}{F_B + F_D} \qquad (5)$$

where:

F_B = Background Flow in ZID, cfs
T_B = Background Temperature, °C
F_D = Discharge Flow, cfs
T_D = Discharge Temperature, °C

4. Calculation of the Wasteload Allocation

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) \qquad (6)$$

where:

C_b = Background concentration, mg/l
Q_b = Stream flow in the MZ or ZID, cfs
Q_o = Effluent flow, cfs
C_s = Applicable water quality standard, mg/l
C_o = WLA concentration, mg/l

This equation is solved for C_o, resulting in wasteload allocations for the protection of both the acute and chronic criteria. These wasteload allocation values are then carried forward to the Permit Derivation Procedure section (pages 55-56).

5. Visible Dye Studies

Where visible dye studies have been done, the ammonia WLA calculations will use the percentage of stream flow in the MZ study as the MZ percentage at the critical design flow. If an analytical Fluorometer dye study is performed, the study results projected to the $30Q_{10}$ flow regime will be used to calculate the MZ flow. This MZ flow will be that value associated with diluting the effluent concentration to the maximum dye concentration at the MZ boundary. This is the required stream flow necessary to assure that the water quality standards are not exceeded at any location across the MZ boundary.

6. Final Ammonia Nitrogen WLA

Once the above input values are determined, the mass balance calculations, the ammonia decay relationship, or the algal uptake equation can be used to arrive at the applicable ammonia nitrogen (NH_3-N) WLAs. The ammonia decay and algal uptake equations used in the modified Iowa Model or QUAL-II model will account for the limited loss of ammonia in a general use reach. These equations will be used when a WLA indicates an ammonia limit more stringent than secondary treatment. It is important to point out that even though the ammonia WLAs are calculated monthly, the QUALII model will only be run seasonally. These seasons are: Summer (July through August), Winter (November through March), and Spring/Fall (April through June/September through October). The WLA calculations will assure that the acute criterion is met by using the allowed stream flow of the ZID, and that the chronic criterion is met by using the dilution of the flow contained in the MZ.

D. Total Residual Chlorine: Total Residual Chlorine (TRC) effluent limits will be calculated for any wastewater treatment facility discharging TRC into or impacting one of the four Class B waters and general uses. The applicable stream standard criteria are listed in Subrule 61.2(5) of the Water Quality Standards.

<u>Calculations</u>

Two types of calculations are available for determining effluent limits: hand calculations, noted above for toxics, and first order decay of TRC. The Iowa Department of Natural Resources (IDNR) has a spreadsheet available on Microsoft Excel to solve for the TRC decay equation when it is applicable. The TRC decay equation is only used to calculate TRC decay in the general use reach. Background flow, defined as the sum of all upstream flows and any incremental flows along the modeled reach, can be added at one of the three reach entries on the Microsoft Excel spreadsheet. The incremental flows should be included at the appropriate distance below the discharge. Most calculations will use the mass balance hand calculations for Toxic Parameters (pages 12-13) described previously.
It is important to point out the major change regarding TRC WLAs. In addition to the TRC decay calculations for the general reach, a TRC loss of 300 µg/l is assumed in the Zone of Initial Dilution (ZID) and the Mixing Zone (MZ) of designated streams.

Two sets of example calculations will be shown for TRC: one for a general use water receiving an upstream wastewater treatment plant discharge with a zero background flow, and one for a discharger to a general use water on which a background or upstream flow exists.

<u>TRC Calculations with Zero Background Flow</u>

Two steps are used in the calculation of a TRC Wasteload Allocation (WLA) for a general use water receiving an upstream wastewater treatment plant discharge with a zero background flow. The first step is needed only if the discharge is directly into a designated stream. Both the mass balance equation (including 300 µg/l TRC loss) and the TRC decay equation are used in these situations. The $7Q_{10}$ and $1Q_{10}$ flows will be used in the following examples. The calculation of a TRC WLA will use the applicable design low flow.

First, the $WLA_{chronic}$ and WLA_{acute} values are calculated using the modified TRC mass balance equation in the designated portion of the receiving stream. Second, the more stringent $WLA_{acute\ or\ chronic}$ value is used in the TRC decay equation to calculate the allowable WLA just downstream of the outfall in the general reach. The overall situation for this type of WLA is shown in the TRC Decay with Zero Background Flow Diagram Examples (Diagrams 1, 2, and 3).

First Step:

The following modified TRC mass balance equation is used for solving for C_o.

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ C_o \tag{7}$$

where:

C_b = Background TRC concentration in Class B stream, µg/l
Q_b = Stream flow in the mixing zone, zone of initial dilution, or general class stream, cfs
Q_o = Effluent flow, cfs
C_s = The water quality standard concentration in the mixing zone or zone of initial dilution, µg/l
C_o = WLA TRC concentration, µg/l

Additional information about modified TRC mass balance equation:

C_b and Q_b are background levels
C_o and Q_o are discharge levels
C_s is the water quality standards (chronic or acute)

<u>Example of modified TRC Mass Balance Equation:</u>

The modified TRC mass balance equations are calculated for the Mixing Zone (MZ) and Zone of Initial Dilution (ZID) to find the chronic wasteload allocation and the acute wasteload allocation.

WLA $_{chronic}$ Calculation Example (using the MZ):

(This calculation must be done for both ADW and AWW flows.)

where:

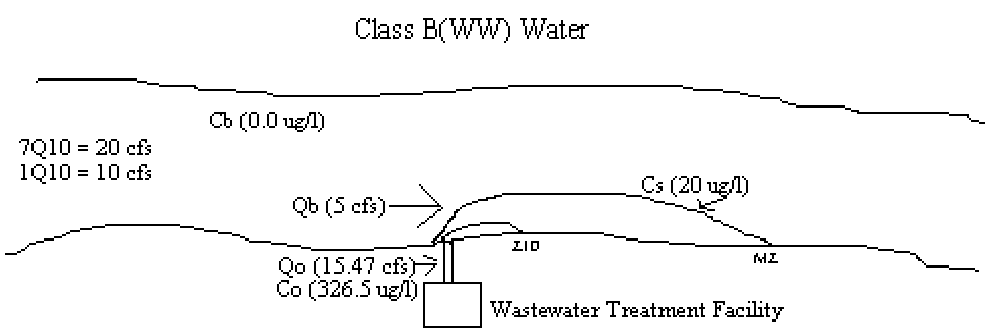
using $7Q_{10}$ = 20 cfs, $1Q_{10}$ = 10 cfs
C_b = 0.0 µg/l
$Q_b = ¼(7Q_{10}) = 20/4 = 5$ cfs
Q_o = 10 mgd (15.47cfs)
C_s = 20 µg/l chronic criterion

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ C_o$$
$$(0.0)5 + C_o(15.47) = 20(5 + 15.47) + 300(15.47)$$
$$0 + C_o(15.47) = 20(20.47) + 300(15.47)$$
$$C_o = \frac{20(20.47)}{15.47} + 300$$
$$C_o = 326.46 = 326.5\ \mu g/l\ \text{WLA}_{chronic}$$

WLA $_{chronic}$ Diagram for Shoreline Discharge:

Diagram 1 illustrates a shoreline discharge to a designated stream. The following diagram illustrates the above WLA $_{chronic}$ Calculation Example.

Diagram 1:



KEY:

$7Q_{10}$ = 20 cfs
$1Q_{10}$ = 10 cfs
C_b = Background TRC concentration, ug/l
Q_b = Stream flow in MZ, cfs
Q_o = Effluent flow, cfs
C_s = Water quality standard concentration in the MZ, ug/l
C_o = WLA chronic, ug/l

WLA $_{acute}$ Calculation Example (using the ZID):

(This calculation must be done for both ADW and AWW flows.)

where:

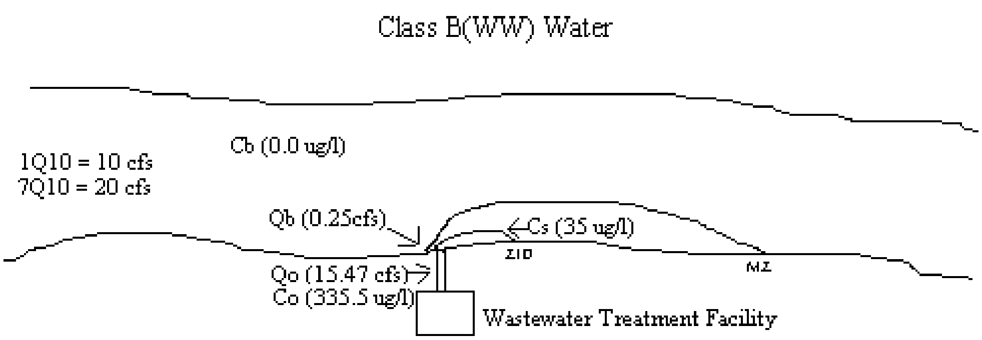
using $1Q_{10} = 10$ cfs
$C_b = 0.0$ µg/l
$Q_b = 1/40(1Q_{10}) = 10/40 = 0.25$ cfs
$Q_o = 10$ mgd (15.47 cfs)
$C_s = 35$ µg/l acute

$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ C_o$
$(0.0)0.25 + C_o(15.47) = 35(0.25 + 15.47) + 300(15.47)$
$0 + C_o(15.47) = 35(15.72) + 300(15.47)$
$C_o = \frac{35(15.72)}{15.47} + 300$
$C_o = 335.5$ µg/l WLA $_{acute}$

WLA $_{acute}$ Diagram for Shoreline Discharge:

Diagram 2 illustrates a shoreline discharge to a designated stream. The following diagram illustrates the above WLA $_{acute}$ Calculation Example.

Diagram 2:



KEY:

$1Q_{10} = 10$ cfs
$7Q_{10} = 20$ cfs
C_b = Background TRC concentration, ug/l
Q_b = Stream flow in ZID, cfs
Q_o = Effluent flow, cfs
C_s = Water quality standard concentration in the ZID, ug/l
C_o = WLA acute, ug/l

Second Step:

The decay model uses a standard first order expression in which the time of travel in the stream reach is incorporated into the calculations. The model expression noted in the EPA's "*Technical Guidance Manual for Performing Wasteload Allocations; Book 2, Chapter 3, Toxic Substances*" June 1984, Appendix D, is used for TRC decay. The TRC decay equation is used when there is a discharge to a general use water (having zero flow). The decay equation will project the amount of TRC loss along the general use reach. The resulting WLA is more relaxed than the WLA calculated in the mass balance equation for the direct discharge to the designated reach. The following TRC decay equation is used, solving for C_d.

$$C_d = C_o e^{(kt)} \qquad (8)$$

where:

C_d = TRC upstream discharge concentration at time t, µg/l
C_o = WLA TRC concentration, µg/l
k = Decay rate constant, day $^{-1}$
t = Time of travel in modeled reach, day

The more stringent of the WLA $_{\text{acute or chronic}}$ from the first step is used in the second step. For these examples, the more stringent of the WLA $_{\text{acute or chronic}}$ is the WLA $_{\text{chronic}}$ value of 326.5 µg/l. This value will be used for C_o in the TRC decay with zero background flow example.

TRC Decay with Zero Background Flow Example:

where:

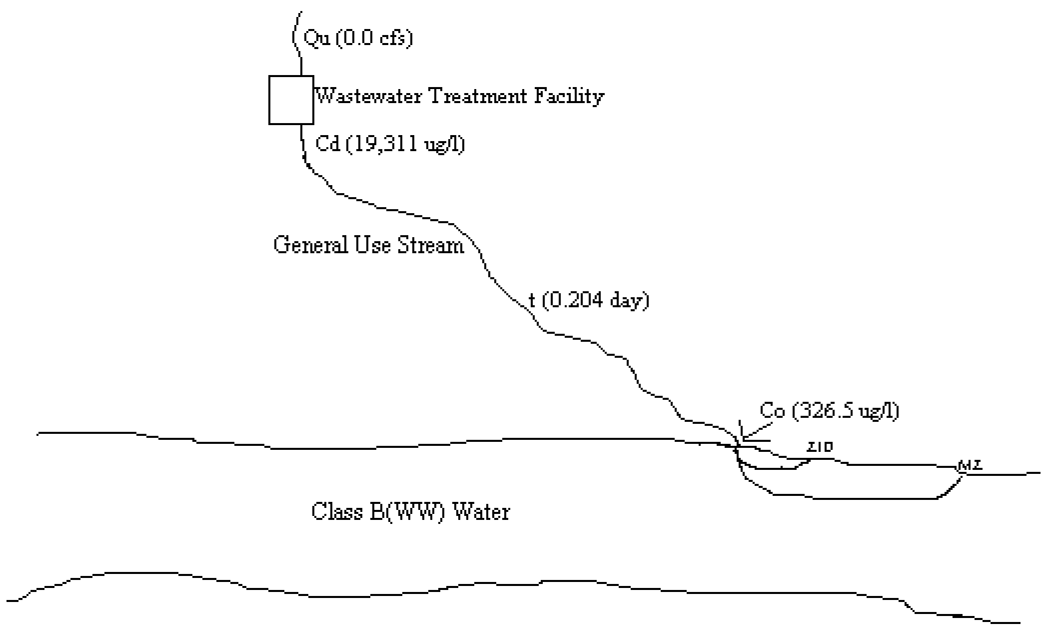
$C_o = WLA_{chronic}$ = 326.5 µg/l
k = 20 day $^{-1}$
t = 0.204 day (1760 ft. upstream at 0.1 ft./sec.)
t = d/v = 1760/0.1 = 17,600 sec.
17,600 sec./86,400 (sec. in a day) = 0.204 day

$C_d = C_o e^{(kt)}$
$= 326.5e^{(20)(0.204)}$
= 326.5(59.145)
C_d = 19,311 µg/l

TRC Decay Diagram with Zero Background Flow:

Diagram 3 illustrates TRC decay along a general use stream into a Class B(WW) Water.

Diagram 3:



KEY:

Q_u = Background or upstream flow, cfs
C_d = TRC upstream discharge concentration at time t, ug/l
C_o = WLA TRC concentration, ug/l
k = Decay rate constant, 20 day $^{-1}$
t = Time of travel in modeled reach, day

<u>TRC Calculations with Background Flow</u>

Three steps are used to calculate the WLA for a discharger to a general use stream on which a background (or upstream) flow exists. Both the modified TRC Mass Balance and the TRC decay equations are used in this situation. First, the $WLA_{chronic}$ and WLA_{acute} values are calculated using the modified TRC Mass Balance equation for the designated portion of the receiving stream. Second, the WLA $_{\text{chronic and acute}}$ for ADW flow and the WLA $_{\text{chronic and acute}}$ for AWW flow are used in the TRC decay equation to calculate the allowable WLA just downstream of the outfall in the general reach. Finally, the actual WLAs for the outfall are calculated using the modified TRC mass balance equation and the upstream flow and concentration. The overall situation for this type of WLA is shown in the TRC Decay with Background Flow Diagram Examples (Diagrams 4,5,6, and 7).

First Step:

The modified TRC mass balance equation in designated water:

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ C_o \qquad (9)$$

WLA $_{chronic}$ Calculation with Background Flow Example (using the MZ):

(This calculation must be done for both ADW and AWW flows.)

where:

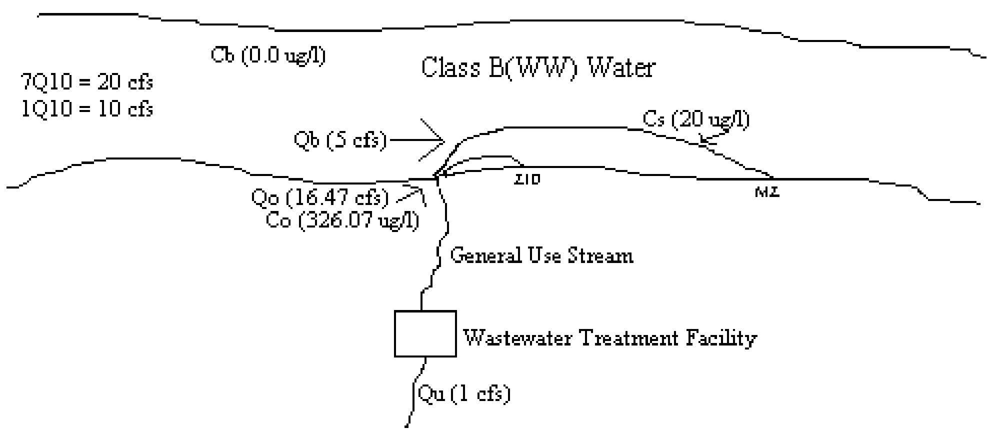
using $7Q_{10}$ = 20 cfs
C_b = 0.0 µg/l
Q_b = ¼($7Q_{10}$) = 20/4 = 5 cfs
$Q_o = \Sigma(Q_D + Q_u)$
Q_D = Discharge flow = 10 mgd (15.47 cfs)
Q_u = Background or upstream flow (1 cfs)
$Q_o = \Sigma(15.47 + 1)$
Q_o = 16.47 cfs
C_s = 20 µg/l chronic

$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ Q_o$
$(0.0)5 + C_o(16.47) = 20(5 + 16.47) + 300\ (16.47)$
$0 + C_o(16.47) = 20(21.47) + 300\ (16.47)$
$C_o = \frac{20(21.47)}{16.47} + 300$
C_o = 326.07 µg/l WLA $_{chronic}$

WLA $_{chronic}$ Diagram with Background Flow:

Diagram 4 illustrates a discharge to a general use stream that discharges into a designated stream on which a background (or upstream) flow exists. The following diagram illustrates the previous WLA $_{chronic}$ Calculation with Background Flow Example.

Diagram 4:



KEY:

$7Q_{10}$ = 20 cfs
$1Q_{10}$ = 10 cfs
C_b = Background TRC concentration, ug/l
Q_b = Stream flow in MZ, cfs
Q_o = Sum of discharge flow and background flow, cfs
C_s = Water quality standard concentration in the MZ, ug/l
Q_u = Background or upstream flow, cfs
C_o = WLA chronic, ug/l

WLA $_{acute}$ Calculation with Background Flow Example (using the ZID):

(This calculation must be done for both ADW and AWW flows.)

where:

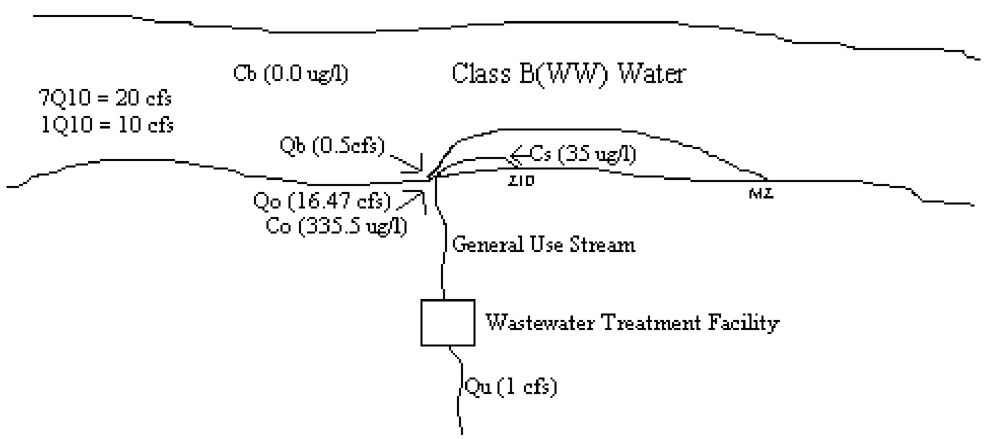
using $1Q_{10}$ = 10 cfs
C_b = 0.0 µg/l
$Q_b = 1/40(1Q_{10}) = 10/40 = 0.25$ cfs
$Q_o = \Sigma(Q_D + Q_u)$
Q_D = Discharge flow = 10mgd (15.47 cfs)
Q_u = Background or upstream flow (1 cfs)
$Q_o = \Sigma(15.47 + 1)$
Q_o = 16.47 cfs
C_s = 35 µg/l acute

$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o) + 300\ Q_o$
$(0.0)0.25 + C_o(16.47) = 35(0.25 + 16.47) + 300\ Q_o$
$0 + C_o(16.47) = 35(16.72) + 300\ Q_o$
$C_o = \frac{35(16.72)}{16.47} + 300$
C_o = 335.5 µg/l WLA_{acute}

WLA $_{acute}$ Diagram with Background Flow:

Diagram 5 illustrates a discharger to a general use stream that discharges into a designated stream on which a background (or upstream) flow exists. The following diagram illustrates the previous WLA $_{acute}$ Calculation with Background Flow Example.

Diagram 5:



KEY:

$7Q_{10}$ = 20 cfs
$1Q_{10}$ = 10 cfs
C_b = Background TRC concentration, ug/l
Q_b = Stream flow in ZID, cfs
Q_o = Sum of discharge flow and background flow, cfs
C_s = Water quality standard concentration in the ZID, ug/l
Q_u = Background or upstream flow, cfs
C_o = WLA acute, ug/l

Second Step:

The WLA $_{chronic\ or\ acute}$ for ADW flow and WLA $_{chronic\ or\ acute}$ for AWW flow from the above step are used in the TRC decay equation. For this example, the more stringent of the WLA $_{chronic\ or\ acute}$ is the WLA $_{chronic}$ value of 326.07 µg/l. The TRC decay over time "t" is used to calculate the upstream concentration (C_o). The following TRC decay equation for an upstream general waterway with background flow is used for solving for C_{db}.

$$C_{db} = C_o e^{(kt)} \tag{10}$$

where:

C_{db} = TRC upstream discharge concentration at time t, µg/l considering background flow (just below outfall)

C_o = WLA TRC upstream concentration, µg/l

k = Decay rate constant, day $^{-1}$

t = Time of travel in modeled reach, day

TRC Decay for Upstream General Waterway with Background Flow Example:

where:

$C_o = WLA_{chronic} = 326.07$ µg/l

k = 20 day $^{-1}$

t = 0.204 day

$C_{db} = C_o e^{(kt)}$

$= 326.07e^{(20)(0.204)}$

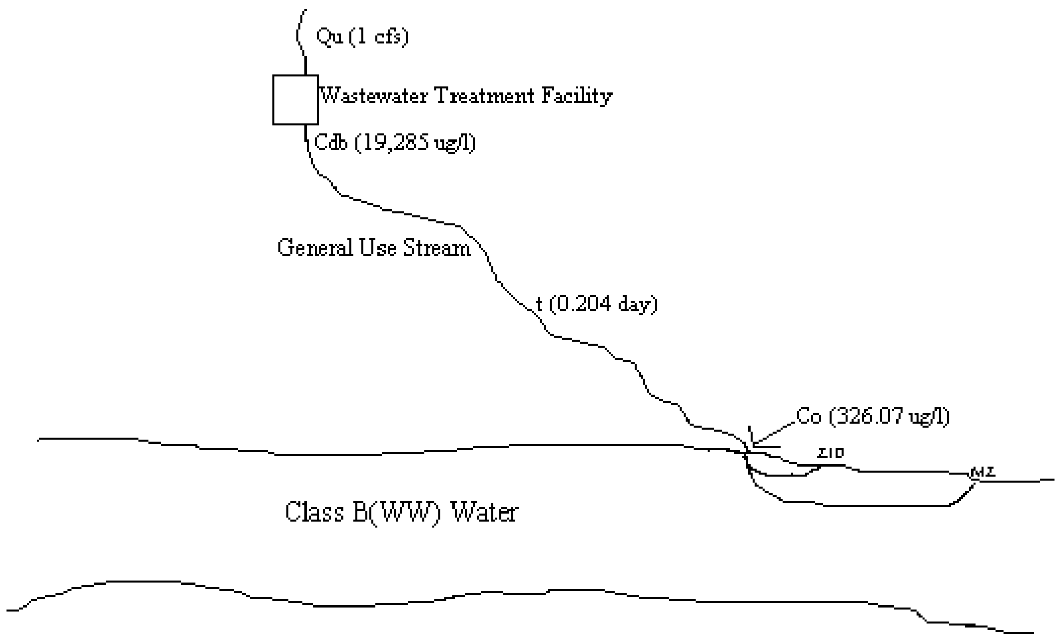
$= 326.07(59.145)$

$C_{db} = 19{,}285$ µg/l

TRC Decay Diagram with Background Flow:

Diagram 6 illustrates TRC decay along a general use stream that discharges into a Class B(WW) water with a background flow.

Diagram 6:



KEY:

Q_u = Background or upstream flow, cfs
C_{db} = TRC upstream discharge concentration at time t, ug/l (just below outfall)
C_o = WLA TRC concentration, ug/l
k = Decay rate constant, 20 day $^{-1}$
t = Time of travel in modeled reach, day

Third Step:

The discharge flow, upstream TRC concentration, upstream flow in the general reach, and the calculated C_{db} from above will be used in the basic mass balance equation to calculate the amount of TRC for the outfall. In the mass balance equation the effluent concentration (WLA) is noted as C_d.

$$C_uQ_u + C_dQ_d = C_{db}(Q_u + Q_d) \qquad (11)$$

where:

C_u = Background TRC concentration in General Use stream, µg/l
Q_u = Background or upstream flow in the general reach, cfs
Q_d = Effluent flow, cfs
C_{db} = Discharge TRC concentration, µg/l considering background flow
C_d = TRC discharge (outfall) concentration at time "t", µg/l

TRC Mass Balance Equation at Outfall Location Calculation Example:

where:

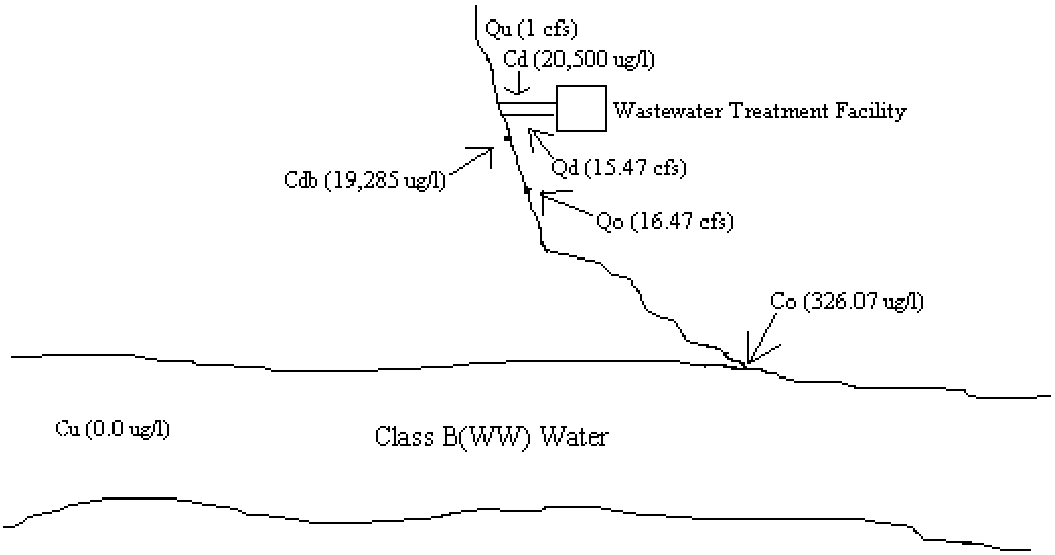
C_u = 0.0 µg/l
Q_u = 1 cfs
Q_d = 10 mgd (15.47cfs)
C_{db} = 19,285 µg/l

$C_uQ_u + C_dQ_d = C_{db}(Q_u + Q_d)$
$(0.0)1 + C_d(15.47) = 19{,}285(1 + 15.47)$
$0 + C_d(15.47) = 19{,}285(16.47)$
$C_d = \dfrac{19{,}285(16.47)}{15.47}$
C_d = 20,500 µg/l (20.5 mg/l) TRC discharge (outfall) concentration at time 't"

TRC Mass Balance Equation Diagram at Outfall Location:

Diagram 7 illustrates the amount of TRC WLA for the outfall. The following diagram illustrates the previous mass balance equation.

Diagram 7:



KEY:

Q_u = Background or upstream flow, cfs
C_d = TRC discharge (outfall) concentration at time t, ug/l
Q_d = Effluent flow, cfs
C_{db} = Discharge TRC concentration, ug/l considering background flow
Q_o = Sum of discharge flow and background or upstream flow, cfs
C_u = Background TRC concentration in Class B stream, ug/l